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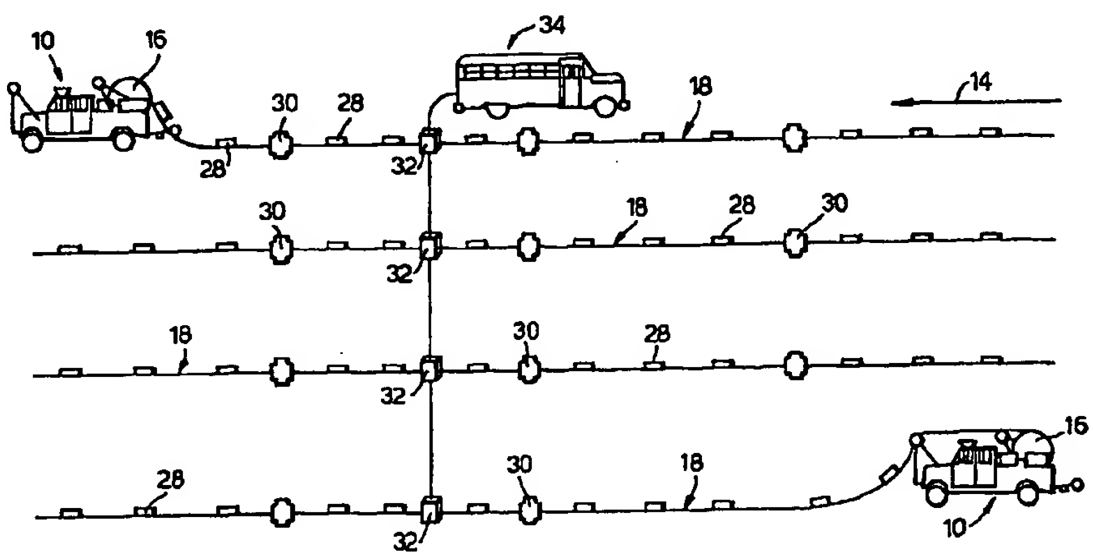

(57) Abstract

A method for land seismic data acquisition is provided, together with a seismic cable and a cable spool vehicle for use in the method. In performing the method, the cable spool vehicle automatically deploys seismic cable with attached sensors according to a desired geophysical spread and at a rate dependent upon the speed of movement of the vehicle substantially without tension in the cable. The cable spool vehicle also allows automatic pick-up of the seismic cable together with the sensors after the seismic data acquisition.

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LAND SEISMIC DATA ACQUISITION METHOD AND SEISMIC CABLE AND CABLE SPOOL VEHICLE THEREFOR

Background of the Invention

Field of the Invention

The present invention relates to a method of performing land seismic data acquisition, and a seismic cable and a cable spool vehicle therefor. More particularly, the invention relates to a method and apparatus for mechanically deploying seismic cable with attached sensors according to a desired geophysical spread and for allowing subsequent mechanical pick-up of the seismic cable together with the sensors.

Description of the Prior Art

In most conventional land seismic data acquisition, individual analog seismic sensors, so-called geophones, typically having one or more spikes attached to their cases, are planted in groups in the ground with the centre of gravity of the group along a seismic survey line. In order to ensure a proper and stable acoustical coupling of the geophones with the ground, each geophone is normally driven into the soil by a vigorous blow on its top applied by a seismic crew member. Before the planting of each geophone, the crew member has to estimate the desired proper position (with respect to geophysical requirements) for the geophone, which is usually realised by simple visual estimation of the geophone position versus a survey peg placed in the centre of gravity of the geophone group. Additionally, the crew member has to plant the geophone so that it is vertical. Grouping the analog output signals of a certain number of geophones and adding their output signals permits the noise signals that are normally superimposed on the seismic signal, such as the horizontally travelling wave (ground roll) and various types of random, incoherent noise (eg wind, rain, scratching of the geophone caused by

moving plants, oscillation of the geophone cable) to be significantly reduced. Each such group of geophones is connected to seismic data acquisition and recording units.

Conventional land seismic data acquisition demands a large number of geophones and cables, together with a large crew and considerable logistics, to lay out the desired geophysical spread and to pick it up again after the seismic survey. Such operations are very time consuming and very expensive.

In order to reduce the setting up time and expense of land seismic data acquisition, in particular the number of crew members required, it has been proposed in the past to apply a marine seismic survey technology, ie streamer technology, to land seismic operations. Here, a multiplicity of sensors are arranged in a line and, instead of being "statically" laid out by being individually planted, are dragged over the ground along a desired seismic survey line.

One such known land seismic streamer comprises a flat band-like device with incorporated interconnected single-component analogue geophones, which, like a marine streamer, was towed by a vehicle, and dragged over ground covered with snow and ice. On the one hand, the flatness of this streamer helped to avoid turning over the streamer and to keep the geophones in a proper upright position. On the other hand, the required good acoustical coupling of the streamer to the ground surface could not be reliably achieved. The flat streamer, because of being dragged and stretched, could not properly follow the contours of the ground, and tended to be drawn over the high points of the ground and to remain stretched without touching the lowerpoints. Furthermore, the flat streamer was very sensitive to wind, which caused significant noise that became superimposed on the desired seismic signal. Another drawback of the flat streamer was that its sensors were incorporated into more or less flexible band sections that alternated with stress compensating members. Replacement of a defective geophone required the replacement of a complete streamer section, a costly action. It is also evident that when such a streamer is pulled and dragged over a dry ground surface, (ie sharp-edged stones,

sand grains etc), it will be heavily affected by abrasion effects and, in the case of sand, by electrostatic effects.

Another prior art land streamer device comprises a main cable with integrated stress compensation members that is also towed behind a vehicle and dragged over the ground. Unlike the aforementioned flat cable streamer, this other streamer did not contain geophones that were mounted as part of the main cable, but rather geophones that were attached to additional secondary cables connected to the main cable via outlet connectors at regular intervals. In order to compensate for improper sensor orientation, the geophones used in this streamer were single component gimbal-mounted analogue sensors. But such geophones only allow compensation for a single axis inclination. And the drawbacks of such a towed land streamer are evident. This streamer too does not always follow the surface contours, or lay properly on the ground or provide sufficient acoustical coupling. Dragging such a streamer over pebbly or rocky ground risks getting it stuck at any restriction in its way. A stuck but still pulled streamer may easily be damaged, destroyed or become a danger for personnel in the field if it unexpectedly frees itself because of the pulling force. The useful life of such a streamer is also very short in view of the abrasion caused by dragging it over the ground.

Summary of the Invention

It is therefore an object of the present invention to provide an improved method for carrying out land seismic data acquisition that avoids at least some of the above described drawbacks of conventional land streamer technology.

According to a first aspect of the present invention, there is provided a land seismic data acquisition method comprising the following steps:

a) in a desired spread for a seismic data acquisition, selecting at least one section of a desired seismic survey line and positioning a cable spool vehicle, which has a cable drum whereon a seismic cable with attached digital seismic sensors

is spooled, at one end of the desired section of seismic survey line, and laying a free end of the cable on the ground;

b) moving the cable spool vehicle along the desired seismic survey line while revolving the drum to let the seismic cable with attached seismic sensors unspool from the drum in such a way that the cable is laid on the ground substantially free of tension; and

c) transmitting acoustic signals into the ground, acquiring the resulting seismic signals with the seismic sensors, and recording the acquired seismic signals in digital form;

said method preferably including one or more of the following further steps:

d) after having finished laying out the seismic cable and attached sensor, stopping the cable spool vehicle and disconnecting the laid out cable from the drum or from cable that still remains on the drum;

e) if necessary, connecting laid-out seismic cable to at least one other laid-out seismic cable on the same seismic survey line or to another laid-out cable along another desired seismic survey line;

f) continuing to lay out seismic cables as in steps a) and b) to complete the desired seismic spread, and interconnecting all the cables to further seismic data acquisition units, such as data recorder means and/or data processing means;

g) driving a cable spool vehicle to a selected seismic cable and disconnecting the selected cable from any adjacent cable and/or from any seismic data acquisition units; and

h) spooling the disconnected cable onto the drum of the seismic spool vehicle while moving the vehicle along the desired seismic survey line.

According to other aspects of the invention, there is provided both a seismic cable for use in the land seismic data acquisition method of the preceding paragraph, the cable comprising at least one main cable and several outlet cables attached to said main cable at intervals, each one of said outlet cables connecting at least one digital seismic sensor to the main cable, as well as a cable spool vehicle for carrying out the method, the vehicle comprising a drum, and a drum driving mechanism that selectively drives the drum backwards and forwards in order to unspool seismic cable off the drum and to respool seismic cable onto the drum, in which the revolving motion of the drum is controlled and co-ordinated in dependence upon the forward motion of the vehicle.

The major advantage of the method for carrying out land seismic data acquisition according to the invention is that it allows seismic sensors to be placed on the ground without any stress or tension in the seismic cable. Applying this inventive method to the seismic cable according to the invention, in co-operation with the inventive cable spool vehicle, allows proper acoustic coupling of the sensors to the ground to be easily achieved. No dragging action on the seismic cable it involved, thus reducing abrasion and other forms of damage. The digital sensors used in performing to the invention permit compensation for the orientation of the sensors.

More advantageous elements and details of the invention are defined in the claims and will be explained in the following description;

Brief Description of the Drawings

The present invention will be better understood from the following detailed description when taken in conjunction with the attached drawings, of which:

FIG. 1 is a schematic and simplified plan of a seismic survey spread with seismic cable laid out by a method according to the invention;

FIG. 2 is a schematic top view of a first embodiment of a seismic cable according to the invention, laid out for a seismic survey; and

FIG. 3 shows a more detailed top view of part of the cable of FIG. 2, with an attached group of seismic sensors.

Detailed Description of a Preferred Embodiment of the Invention

In FIG. 1, a schematic and simplified plan of a seismic survey spread illustrates how seismic cable is laid out (and picked up again) according to the invention.

A seismic cable spool vehicle 10 (in FIG. 1 this is the upper vehicle) is moved to a desired seismic survey line 14. In FIG. 1 the cable spool vehicle 10 is shown as a self-propelled vehicle, but without limiting the invention this vehicle may also be trailer or the like that is pulled by another type of vehicle. A cable drum 16 mounted on the cable spool truck 10 contains seismic cable 18 (see also FIGS. 2 and 3). A full standard drum 16 preferably carried about 2 - 2.5 km of cable, but other drum sizes are possible if needed. The whole seismic cable 18 on the drum 16 is not made up of a single cable over its total length, but comprises multiple inter-connectable seismic cable segments each of an individual length of preferably about 200 - 300 m. The cable segments may be connected directly to each other or by means of a telemetry unit 28 that will be described later. This allows tailoring the cable 18 for the desired seismic survey line 14 and/or easy replacement of a (relatively short) cable segment that is damaged or otherwise out of order. Even in areas where the cable spool vehicle 10 cannot be easily moved, the cable segments are handy and lightweight enough to be transported and laid out by seismic crew members in the conventional way.

The seismic cable 18 (see FIGs. 2 and 3) consists of a main cable 20 and numerous outlet cables 22, each of which bears several, preferably three, digital seismic sensors 24 that comprise 3-component accelerometers and in a preferred embodiment 3-component magnetometers. The data from these three seismic sensors 24 at each outlet cable 22 (see FIGs. 2 and 3) may be grouped together with digital processing. In FIG. 1, for simplicity reasons, the complete seismic cable is symbolised by a single line.

At the desired seismic survey line 14, the free end of the seismic cable 18 spooled on the drum is laid on the ground. The cable spool vehicle 10 then drives along the seismic survey line 14 while the drum 16 is actively driven to revolve and to actively unspool the seismic cable 18. The seismic cable 18 is laid out upon the ground substantially without any stress or tension, and is neither dragged nor pulled. To achieve this, the speed of the forward movement of the cable spool vehicle 10 is continuously controlled and co-ordinated with a desired revolving speed of the cable drum 16. During unspooling of the seismic cable 18 the speed of the drum 16 is also controlled and, if necessary, readjusted according to the measured tension on the seismic cable 18. Another factor which may require an adjustment of the speed of the drum 16 is the true geographical position of the cable spool vehicle 10. The preferred embodiment of the cable spool vehicle 10 is equipped with an electronic system that determines its geographical position, ie a Global Positioning System (GPS). Such a GPS system enables the driver or an assistant to monitor the actual geographical position of the vehicle 10 with high accuracy, ie to within a few meters, and allows such positioning data to be recorded. According to the invention, not only the truck positioning data are monitored and recorded as the cable spool vehicle 10 follows the desired seismic survey line 14, but also all geographical positioning data that relate to each laid out seismic sensor group.

As also shown in FIG. 1, electronic circuits 28 are placed along the seismic survey line 14. These electronic circuits 28 are so-called signal concentrators that gather and further transmit the digital output signals of the seismic sensors 22 during the seismic data acquisition. These electronic signal concentrators 28 (see also FIG. 2) are placed at

standard intervals along the seismic cable 18 and, in preferred embodiments of the seismic cable 18, are implemented as integrated, relatively small parts of the seismic cable 18 which are also wound on the drum 16 on the cable spool vehicle 10.

Power supply boxes 30, that typically comprise batteries, serve to power up all electronic equipment that is connected to the seismic cable 18, including the seismic sensors 22. Network router units 32 that are linked in a "back-bone" (or "cross-line") scheme allow the seismic cable 18 of one seismic survey line 14 to be connected to the seismic cable of an adjacent seismic survey line and to a seismic data recording vehicle 34. The network router units 32 organise the data transfer between the seismic cables 18 and the cross-lines. FIG. 1 shows that the power supply units 30 are also attached to the seismic cable 18 at standardised intervals. In order to let the aforementioned units 30 and 32 be connected to the seismic cable 18, the cable spool vehicle 10 has to stop at the desired places along the seismic survey line 14. Normally a power supply unit 32 is used at the end of a seismic cable section that equals the cable length that can be spooled on a drum 16.

The laying out of seismic cables 18 is continued in one seismic survey line 14 until the cable spool vehicle 10 has completed the particular survey line, as shown in FIG. 1. The laid out seismic cable 18 is then disconnected from the drum 16 and the cable spool vehicle 10 moves to another seismic survey line. In a case where more seismic cable 18 is needed than there is still on its drum 16, the cable spool vehicle 10 may receive a replacement full drum.

When all the cables 18 are in place and interconnected in a seismic spread for a seismic data acquisition, a line test is performed to verify that all sensors, cables and attached electronic units work properly. After replacement of improperly working equipment if necessary, the seismic data acquisition is carried out in a way that in principle is known to those skilled in the art.

One advantage of a seismic data acquisition according to the invention resides in the fact that the digital seismic sensors, the aforementioned 3-component accelerometers, which are used allow the measurement of gravity related signals. Together with measurements from the 3-component magnetometer, this allows a transformation of the actually measured seismic signal components into a desired reference co-ordinate system. The entire signal related data transfer on the seismic cables in the survey spread is digital. The power distribution along the survey lines is performed over relatively long distances that equal about the maximum cable length on the drum of the cable spool vehicle.

FIG. 1 also illustrates how easily the seismic cable 18 can be picked up again according to the invention. In order to do so, the cable spool vehicle 10 (in the drawing the lower vehicle), now with an empty drum 16, is moved to a seismic survey line from which the seismic cable 18 is to be removed. In principle, the respooling of the seismic cable 18 on the drum 16 is performed the same way as laying out the seismic cable 18. At each place where power units 30 and network router units 32 are attached to the cable 18, the spool truck 10 stops, and after the disconnection of each unit the cable is connected to the cable that is already spooled on the drum 16 and then wound thereon. A cable test may be run before a cable section is spooled on the drum 16. This allows the identification of defective cable segments and/or sensors that are out of order, so that they can be replaced or removed before spooling. This makes sure that only properly working seismic cable and sensors are on a drum, and that the spool truck may directly lay out the just respooled cable at another place if needed.

Usually more than one cable spool vehicle 10 will be used at once, as shown in FIG. 1. Thus sections of seismic cable 18 which are no longer needed for the seismic survey can be picked while at the same time at a different position another truck 10 may lay out sections of seismic cable 18 required for a following part of the seismic survey.

FIGs. 2 and 3 show the seismic cable 18 in more detail. At regular intervals 40, preferably around 50 m, the main cable is equipped with cable take outs 38 that mechanically as well as electrically connect the outlet cables 22 and the seismic sensors

24 to the main cable 20. The take outs 38 allow the quick disconnection of an outlet cable 22 from the main cable 20 if the seismic sensor group has to be replaced or just to be left out. This ensures full liberty to the user to realise various forms of seismic survey lines or seismic spreads. After a certain number of take outs 39 along the main cable 20, the electronic signal concentrators 28 are integrated into the seismic cable 18 as shown. Their function as telemetry units has been already described above. The interval 42 is always an odd multiple of the interval 40 between two take outs 38, because this guarantees that signal concentrators 28 are always placed in the middle between two adjacent take outs 38.

Supplemental to the elements already illustrated in FIG. 2, FIG. 3 shows that, according to a preferred embodiment of the invention, elastic links or strings 44 are used to make sure that the outlet cable 22 and its seismic sensors 24 lie essentially in close an parallel to the main cable 20. On one hand the elasticity of the links 44 allows a deployed outlet cable 22 to lie against and follow the contours of the ground surface for proper acoustical coupling of the seismic sensors 24 to the soil. On the other hand the elastic links 44 keep the outlet cables 22 close to the main cable 20 during any spooling operation. This avoids bulky parts that may hinder easy spooling or that could be torn off or destroyed during spooling operation.

CLAIMS

1. A land seismic data acquisition method comprising the following steps:

   a) in a desired spread for a seismic data acquisition, selecting at least one section of a desired seismic survey line and positioning a cable spool vehicle, which has a cable drum whereon a seismic cable with attached digital seismic sensors is spooled, at one end of the desired section of seismic survey line and laying a free end of the cable on the ground;

   b) moving the cable spool vehicle along the desired seismic survey line while revolving the drum at a rate dependent upon the speed of movement of the vehicle to let the seismic cable with attached seismic sensors unspool from the drum in such a way that the cable is laid on the ground substantially free of tension; and

   c) transmitting acoustic signals into the ground, acquiring the resulting seismic signals with the seismic sensors, and recording the acquired seismic signals in digital form.

2. The method of claim 1, further comprising, after having finished laying out the seismic cable and attached sensors, stopping the cable spool vehicle and disconnecting the laid out cable from the drum or from cable that still remains on the drum.

3. The method of claim 1 or claim 2, further comprising connecting laid-out seismic cable to at least one other laid-out seismic cable on the same seismic survey line or to another laid-out cable along another desired seismic survey line.

4. The method of any preceding claim, further comprising continuing to lay out seismic cables as in steps a) and b) to complete the desired seismic spread, and

connecting all the cables to seismic data acquisition means, such as data recorder means and/or data processing means, which perform the recording step.

5. The method of any preceding claim, further comprising driving a cable spool vehicle to a selected seismic cable and disconnecting the selected cable from any adjacent cable and/or from any seismic data acquisition units, and spooling the disconnected cable onto the drum of the seismic spool vehicle while moving the vehicle along the desired seismic survey line at a spooling rate dependent upon the speed of movement of the vehicle.

6. The method of any preceding claim, wherein a data transfer test is carried out along the seismic cable before it is spooled on the drum.

7. The method of claim 6, wherein the proper function of the seismic sensors is tested together with the data transfer test along the seismic cable.

8. The method of any preceding claim, wherein the seismic sensors are three-component seismic sensors.

9. A seismic cable for use in a land seismic data acquisition method according to any one of the preceding claims, the cable comprising at least one main cable and several outlet cables removably attached to said main cable at intervals, each one of said outlet cables connecting at least one digital seismic sensor to the main cable.

10. A seismic cable according to claim 9, wherein each digital seismic sensor comprises a 3-component feedback controlled accelerometer which is also arranged to produce gravity related signals.

11. A seismic cable according to claim 10, wherein each seismic sensor is equipped with a 3-component magnetometer having its component axes parallel to the component axes of the 3-component accelerometer.

12. A seismic cable according to any one of claims 9 to 11, wherein at least three seismic sensors are connected to each outlet cable.

13. A seismic cable according to any one of claims 9 to 12, wherein a power supply unit is connected to the or each main cable.

14. A seismic cable according to any one of claims 9 to 13, wherein an electronic telemetry unit is connected to the or each main cable.

15. A seismic cable according to claim 14, wherein the or each electronic telemetry unit is an integrated part of its cable.

16. A seismic cable according to any one of claims 9 to 15, wherein the or each main cable comprises a plurality of inter-connectable and disconnectable cable segments.

17. A seismic cable according to claim 16, wherein each seismic main cable segment comprises at least three outlet cables.

18. A cable spool vehicle for use in land seismic data acquisition, the vehicle comprising a drum, and a drum driving mechanism that selectively drives the drum backwards and forwards in order to unspool seismic cable off the drum and to respool seismic cable onto the drum, in which the revolving motion of the drum is controlled and co-ordinated in dependence upon the forward motion of the vehicle.

19. A cable spool vehicle according to claim 18, further comprising means for periodically determining the geographical position of the vehicle and for recording such positions in the form of a vehicle trajectory.

20. A cable spool vehicle according to claim 19, wherein the position determining means comprises Global Positioning System equipment.

21. A cable spool vehicle according to any one of claims 18 to 20, further comprising at least one sensor that determines the tension on the seismic cable during the unspooling operation.

22. A cable spool vehicle according to any one of claims 18 to 21, wherein the revolving of the drum for unspooling of the seismic cable is also controlled by the geographical position of the vehicle.

23. A land seismic data acquisition method according to any one of claims 1 to 8, in which several cable spool vehicles are used, and at least one of the vehicles lays out a new seismic cable whilst another vehicle respools a different seismic cable.

Fig.1.

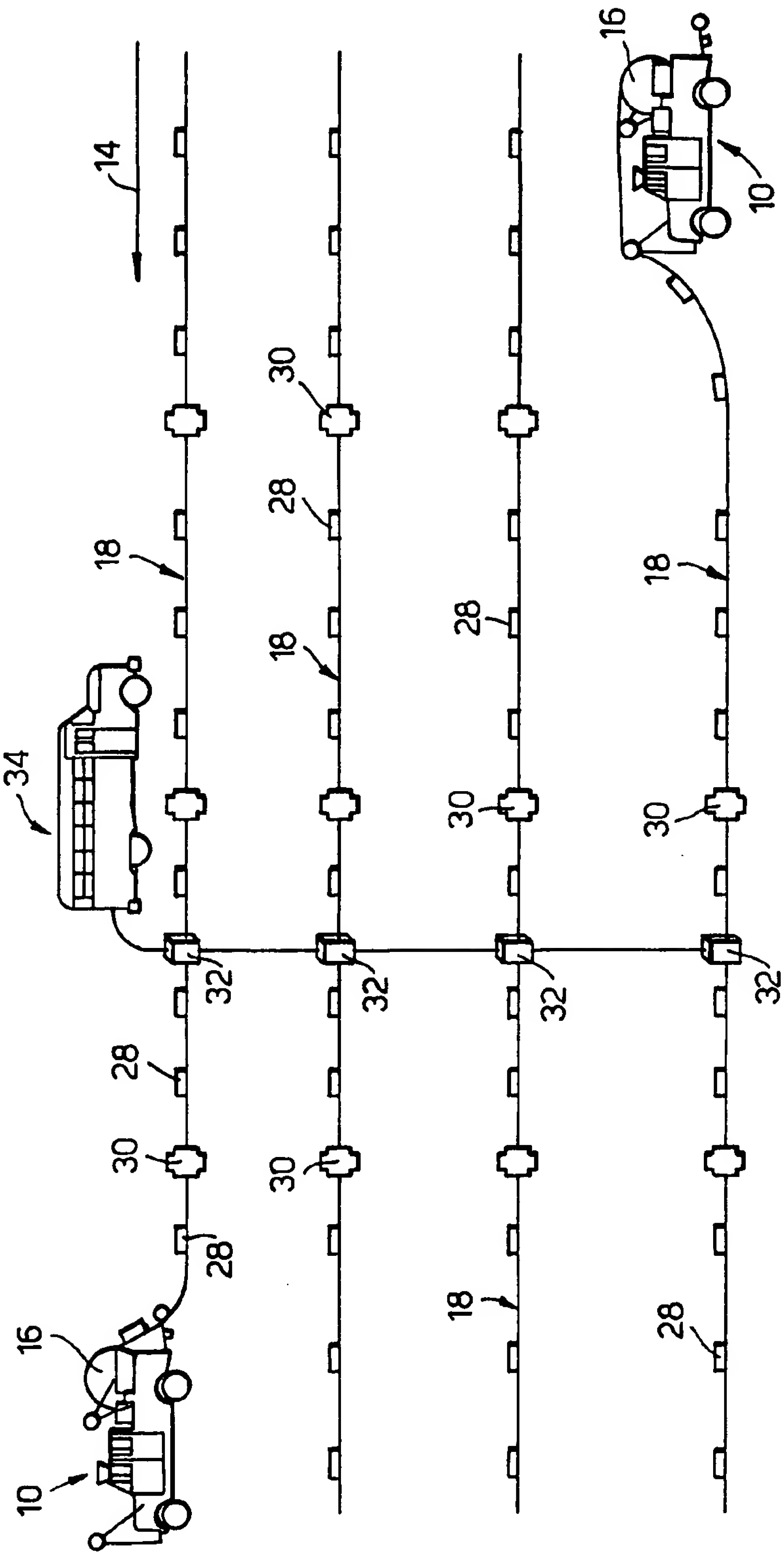


Fig.2.

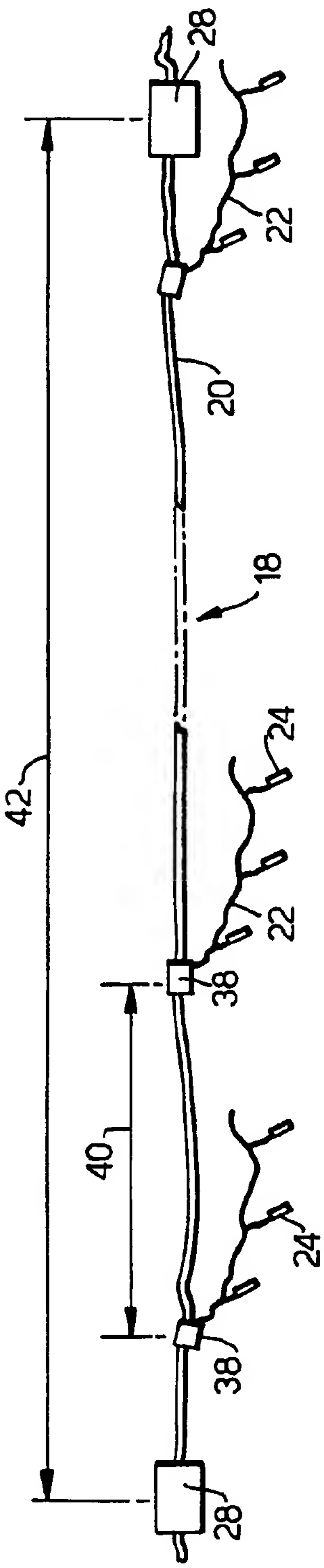
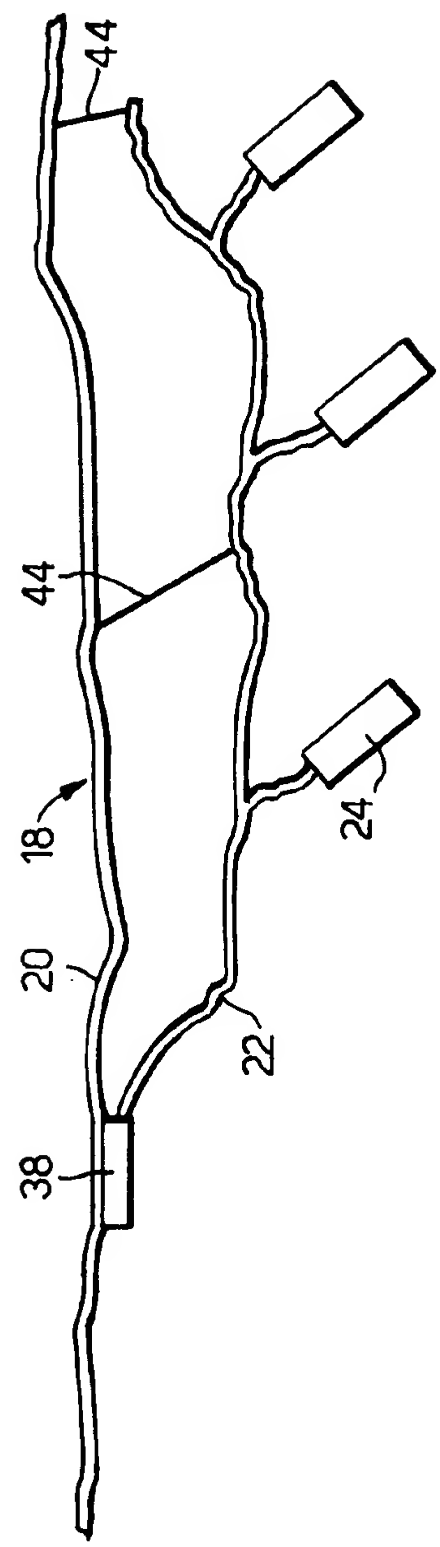


Fig.3.



INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 97/02544

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G01V1/20 G01V1/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G01V

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 677 753 A (IFREMER ;INST FRANCAIS DU PETROL (FR); GEODIA (FR)) 18 October 1995 see abstract see column 2, line 40 - line 53 see column 3, line 15 - column 4, line 17 see column 6, line 53 - column 7, line 36 see figure 2 ---	1
A	US 3 930 219 A (KOSTELNICEK RICHARD J) 30 December 1975 see abstract see figure 1 ---	1
X	SU 1 260 892 A (ZAP SIB OTDEL VNII GEOFIZICHES) 30 September 1986 see abstract see column 2, line 3 - line 20 see figures 1-3 --- -/--	1,5,18

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
15 January 1998	29/01/1998

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	de Heering, Ph.

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

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A	US 4 066 993 A (SAVIT CARL H) 3 January 1978 see abstract	14
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A	see column 1, line 10 - column 2, line 17 see column 4, line 4 - column 6, line 28	5
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3

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Information on patent family members

Inte onal Application No
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